Volume 26 JUNE 25, 1951 Number 5

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAMME OF THE

VANCOUVER MEETING

AT

UNIVERSITY OF BRITISH COLUMBIA

JUNE 25, 26, 27, AND 28, 1951

PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY
SEVEN ISSUES EACH YEAR

BULLETIN

of the

AMERICAN PHYSICAL SOCIETY

Published seven times per year

Subscription price: $5.00 per year

Single copies: $1.00 each

The Bulletin of the American Physical Society is published seven times a year, once in February, once in March, once in April, twice in June, once in October, and once in November, at Prince and Lemon Streets, Lancaster, Pennsylvania.

Entered as second class matter, December 27, 1949, at the post office at Lancaster, Pa., under the Act of August 24, 1912.

Acceptance for mailing at a special rate of postage provided for in paragraph (d-2), Section 34.40, P. L. & R. of 1948, authorized Nov. 30, 1948.

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VANCOUVER MEETING, JUNE 25, 26, 27, AND 28, 1951

THE 307th meeting of the **American Physical Society** will be held at the University of British Columbia in Vancouver, from **Monday through Thursday, June 25 through 28, 1951.** Invited papers will be given by William S. Wilson, Gordon F. Hull, Jr., W. B. Lewis, J. R. Richardson, John H. Williams, R. G. Herb, G. L. Pearson, and W. H. Brattain.

A **registration desk** will be in the main lobby of the Physics Building. Information will be available there. Most of the visitors will be staying at the **Youth Training Centre, Acadia Camp.** Suitable accommodations will be available for single men and women, and married couples with or without children.

Breakfast will be served at the Centre at a rate of from 60¢ to 75¢. All other meals will be taken at the University. The Camp is on the University grounds, but is approximately fifteen minutes walk from the Physics Building.

Post-deadline papers. The Council, availing itself of an amendment to the By-Laws adopted on 30 January 1948, announces that "The Council or its designates will consider the admission, to a special supplementary programme, of a limited number of papers of which the abstracts are received not later than Tuesday, June nineteenth." These abstracts must reach the office of Dr. J. Kaplan (University of California, Los Angeles 24, California) by the specified time. Do not regard this as a guarantee of acceptance. The idea is to make possible the presentation of a small number of very recent achievements of very special importance. The abstracts of the post-deadline papers which are accepted will not be published: the titles will be announced, and the papers will be scheduled for presentation at a convenient time or times during the meeting.

There will be a **Garden Party** on Wednesday afternoon, from 4:30 to 7:30, at the home of Mr. and Mrs. F. Ronald Graham, friends of the University and distinguished residents of Vancouver. There will also be a **Tea Party** at the Faculty Club on Monday afternoon from 4:30 to 6:00. This will be put on by the University, and will give members and their wives an opportunity to get acquainted with the University people.

Prospective meetings of the Society are scheduled for Chicago, October 25–27; Houston, November 23–24; New York City, January 31 and February 1 and 2, 1952. A notice of the Chicago meeting appears in the Schenectady Bulletin. It is expected that there will also be a Winter meeting on the West Coast.

General Rules for Presentation of Papers

The time allowed for the oral presentation of a contributed paper is ten minutes at most. The time allowed for the presentation of each invited paper is stated in the Bulletin.

When two or more contributed papers are submitted by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited, for this purpose, to the first person named on its by-line.) For each paper on this programme a session is indicated, at the end of which it may be offered; but the Chairman is empowered to require that it be given in fewer than ten minutes, or to read it by title.

Titles and abstracts of the papers contributed to the 1951 Vancouver meeting are printed hereinafter exactly as they will stand in a future issue of *The Physical Review*. Errata will be printed on an adjacent page of *The Physical Review* if received not later than Friday, July thirteenth, by Miss Ruth Bryans, 57 East 55 Street, New York 22, New York. Do not send in the abstract marked with corrections; write out the corrections in the form "instead of .... read ....". Do not add new results.

Speakers must retrieve their lantern slides before leaving the hall in which they gave their papers. The Local Committee must not be burdened with the task of saving and returning them.

J. Kaplan
Local Secretary for the Pacific Coast
University of California
Los Angeles 24, California

See Schenectady bulletin for a fuller announcement of the October Meeting in Chicago.

PROGRAMME

MONDAY MORNING AT 10:00

Physics Building, Room 200

(A. M. CROOKER presiding)

Contributed Papers

A1. Ionization Currents and Dissociation in CF_3SF_5. MELVIN A. HARRISON AND RONALD GEBALLE, *University of Washington.*—Measurements of ionization currents in CF_3SF_5[1] have been made with plane-parallel electrodes at values of E/p from 150 to 230 volts/cm/mm. Semi-log plots of these currents against electrode separation at constant E/p do not exhibit the usual behavior. Instead they rise from an initial photoelectric value with a curvature concave downward, become linear for a distance, and eventually curve upward steeply. From slopes of the linear portions can be calculated values of α/p, Townsend's coefficient, which are of similar magnitude to those reported in other complex gases.[2] The initial rise can be attributed to dissociation which occurs in CF_3SF_5 to an unusual extent.[1] The discussion of Warren, Hopwood, and Craggs[3] supports this interpretation. Values of a dissociation coefficient, analagous to α/p, are found to be several times the latter. Ionization currents in O_2 at E/p below 50 volts/cm/mm exhibit a similar initial rise which is probably caused by attachment.[4]

[1] R. Geballe and F. S. Linn, J. Appl. Phys. **21**, 592 (1950).
[2] B. Hochberg and E. Sandberg, C. R. Acad. Sci., USSR **53**, 511 (1946).
[3] Warren, Hopwood, and Craggs, Proc. Roy. Soc. (London) **63**, 180 (1950).
[4] H. S. W. Massey, *Negative Ions* (Cambridge, 1950), second edition.

A2. Electric Field Studies Using Bentonite Suspensions. VIRGINIA P. PLATT AND RONALD GEBALLE, *University of Washington.*—The method suggested by Mueller[1] for studying electrostatic fields by utilizing the electro-optical properties of a monodisperse suspension of bentonite has been applied to two geometries. Photographs of isochromatic (lines of constant field magnitude) and isoclinic (lines of constant field direction) lines have been obtained for plane parallel electrodes as well as plane to plane on edge with various electrode separations and well conditions. For the latter electrode arrangement, off-axis fields have been measured. Checks against solutions of LaPlace's equation have been obtained for certain cases. It was found that very sharp isoclinics with complete elimination of the isochromatics could be obtained by diluting the suspension from 2 percent to 0.2 percent.

[1] Hans Mueller, J. Opt. Soc. Am. **31**, 286–291 (1941).

A3. The X-ray *K* Absorption Edges of Covalently Bonded Nickel, Iron, and Manganese. W. W. BEEMAN AND G. R. MITCHELL,* *University of Wisconsin.*—The *K* absorption edges of covalently bonded nickel in seven compounds are measured with a two-crystal spectrometer. Using Pauling's theory of the chemical bond, the shapes of the absorption edges of covalently bonded manganese,[1] iron,[2] and nickel, within approximately 20 ev of the absorption edge, are given a qualitative interpretation. It is found experimentally that prominent low energy absorption lines can be associated with $1s-4p$ transitions where the final $4p$ state is a nonbonding orbital of the metal atom.

* Now at U. S. Naval Ordnance Test Station.
[1] H. Hanson and W. W. Beeman, Phys. Rev. **76**, 118 (1949).
[2] V. Yoshida, Sci. Pap. of the Inst. of Chem. and Phys. Res. **1015**, 272 (1941).

A4. A Theoretical Estimate of the Effect of Interstitial Atoms and Vacancies on the Elastic Coefficients of Simple Metals.* G. J. DIENES, *Atomic Energy Research Department, North American Aviation, Inc.* (Introduced by M. M. Mills).—Interstitial atoms and vacancies play an important role in the theory of solids and of radiation damage. It is difficult to separate and measure unambiguously these lattice disturbances in metals. It is suggested that measurements of changes in elastic constants may be appropriate in such investigations. An approximate theoretical treatment is given of the change in elastic constants of simple metals caused by the presence of a given small fraction of interstitial atoms and vacancies. The elastic coefficients are calculated from atomic interaction potentials using a simple exponential repulsive interaction for copper and a Morse potential function for sodium. In both cases, the presence of a small fraction of interstitials and vacancies results in large increases in the elastic coefficients, the change being proportional to the fraction of displaced atoms. Lattice vacancies alone were found to decrease the elastic coefficients, the change being essentially a bulk effect. Consequently, increases in the elastic coefficients measure primarily the fraction of interstitial atoms. It is concluded that the theoretically predicted effects should be easily observable experimentally provided thermal annealing is prevented. Changes in elastic constants, therefore, may serve as a useful tool for distinguishing between interstitial atoms and vacant lattice sites.

* This paper is based on work performed under Contract No. AT-11-1-GEN-8 for the AEC.

A5. Experimental Study of Initial Convection in Porous Media: Radioactive Instrumentation. L. E. SCHILBERG AND F. T. ROGERS, JR., *U. S. Naval Ordnance Test Station.*—The onset of convective flow in a water-sand mixture was determined simultaneously by three separate methods:[1] (a) visible motion of dye in the liquid; (b) a change in the heating rate; (c) a change in the counting rate of 0.01–0.1μc of P^{32} (as $H_3P^{32}O_4$ solution[2]) injected by a hypodermic syringe and micropipette. Screened and washed desert sand (of known flow-permeability) and tap water were contained in a 1000 ml beaker heated from below by a commercial type electric "hotplate." Thermocouples attached to a Brown "Electronik" thermograph measured temperatures at approximately 2 cm vertical intervals. Radioactive counting was accomplished by a medical-type, miniature G-M tube immersed in the sand and water mixture, attached to a scale-of-64 circuit, which recorded on a Brush recorder. Data which were obtained are discussed in the following abstract, and are there compared with present theory.

[1] F. T. Rogers, Jr., and L. E. Schilberg, J. Appl. Phys. **22**, 233 (1951).
[2] Furnished by ORNL under U.S.A.E.C. authorization No. 5849.

A6. Experimental Study of Initial Convection in Porous Media: Theory *vs* Experiment. F. T. ROGERS, JR., AND L. E. SCHILBERG, *U. S. Naval Ordnance Test Station.*—By means of the apparatus described in the preceding abstract, we have determined (mean, negative) critical thermal gradients, β_c, at the onset of convection in water in unconcolidated sands; twelve separate experiments were performed, under various conditions. For each experiment we obtained, in addition to such necessary data as flow-permeability, depth, and so on, a

heating-rate parameter, φ, defined by $T=\beta D(1-e^{-\varphi Z/D})/(1-e^{-\varphi})$, where T is temperature excess (at Z) over bottom temperature (at $Z=0$). We have also calculated β_c-values for each experiment by a recent form of the theory,[1] for comparison with experimental values. We wish to report that deviations of theoretical β_c's from observed β_o's, expressed as percents of experimental values, had, for the several methods of flow detection, the following respective average values: Visual, 150 percent, thermal, 36 percent; and radioisotopic, 11 percent.

[1] F. T. Rogers, Jr., and H. L. Morrison, Fourth Annual Heat Transfer and Fluid Dynamics Inst., Stanford University, June, 1951.

A7. Modifications to X-Ray Line Shapes due to Crystal Distortions. EUGENE P. COOPER,* *Naval Ordnance Test Station, Pasadena, California.*—In the study of the mechanism of cold-work, Warren and Averbach (*J. Appl. Phys.* **21**, 595, 1950) have used a fourier analysis of x-ray line shapes to yield the strain-distributions within cold-worked crystals (α-brass). Since the same type of x-ray line broadening has been observed for crystals (graphite), distorted by heavy particle irradiation, it is indicated that similar analytical methods might be used to study the mechanism of radiation damage. The limits of the fourier analysis method have been investigated; its validity becomes questionable in the limit of small crystal distortions. Since much smaller distortions are expected in radiation-damaged metallic crystals than in graphite, other analytical methods are necessary. Various "models" of radiation-damaged crystals have been studied; the comparison of the resulting x-ray line shapes with those of experiment may yield criteria for deciding the essential nature of radiation-damaged crystal structure, but sufficient experimental data are not yet available. The study indicates that the variation of average crystal planar spacing among the crystals of a powder sample is the most effective line-broadening distortion.

* The author did this work as consultant to North American Aviation.

A8. The Effect of Cyclotron Bombardment on Self-Diffusion in Silver.* A. B. MARTIN, R. D. JOHNSON, W. V. GOEDDEL, *Atomic Energy Research Department, North American Aviation, Inc.*—The radioactive tracer method has been used to measure the rate of self-diffusion in polycrystalline silver, and experiments have been performed to investigate the effect on this diffusion process of bombardment with 10-Mev protons from the Berkeley 60-inch cyclotron. Experimental techniques will be described and results will be presented for diffusion samples which were simultaneously irradiated in the cyclotron target box and annealed at 850°C, 800°C, and 750°C, and for control samples which were diffused at several temperatures in the range 900°C to 500°C.

* This paper is based on work performed under Contract No. AT-11-1-GEN-8 for the AEC.

A9. A Study of the Annealing Kinetics in Cold-Worked Copper.* DWAIN BOWEN, R. R. EGGLESTON, AND R. H. KROPSCHOT, *Atomic Energy Research Department, North American Aviation, Inc.*—The resoftening kinetics for cold work in copper have been studied using residual resistance as a measure of the degree of recovery. The specimens were quickly heated to the annealing temperature, held at temperature for a measured time and quenched for measurement. The assumption was made that the cold work could be characterized by a number of lattice defects n, and that these defects obeyed Matthiessen's rule. It was found that the resoftening was well represented by a single process of activation energy 24 kilocalories per mole. The difficulties that previous investigators have had in interpreting their data kinetically have been overcome by allowing reaction orders other than the first. In this case the annealing is well described by a third order reaction. $dn/dt=-\nu n^3 e^{-E/RT}$. Some of the implications of the third-order reaction on the mechanism of resoftening, and on plastic deformation will be discussed.

* This paper is based on work performed under Contract No. AT-11-1-GEN-8 for the AEC.

A10. The Exclusion Principle and the Theory of Superconductivity.* WILLIAM BAND, *The State College of Washington.*—Consider a determinantal eigenfunction formed from any N one-particle free-electron wave function specified by a spectrum of N wave number k-vectors. We prove that the totality of such determinants formed from all conceivable spectra of N k-vectors in k-space forms a closed orthogonal set of determinantal eigenfunctions. Because of this closure theorem the antisymmetrical solution of any problem with N electrons satisfying the exclusion principle can be expressed as a linear combination of these basic determinants. It is then proved that first-order resonance energy due to lattice and phonon interaction with the assembly is proportional to the square root of the volume, $V^{\frac{1}{2}}$, for a given numerical density. The volume V over which the exclusion principle operates is restricted to a region in which the one-electron wave functions overlap. These domains may be identified at sufficiently low temperatures with the domains of phase-coherence among the zero-point Debye modes of vibration. Positive resonance energy favors coherence of the electron gas in one single assembly of maximum possible volume. Implications of this for the theory of superconductivity will be briefly discussed.

* Assisted by the ONR.

MONDAY AFTERNOON AT 2:00

Physics Building, Room 201

(GORDON F. HULL, JR. presiding)

Contributed Papers

B1. Beta-Decay of Para- and Orthotritium. B. A. JACOBSOHN, *University of Washington.*—It is possible in principle to distinguish between Gamow-Teller and Fermi selection rules by observing whether or not the nuclear spin can flip when an electron is emitted. An indirect way of observing this is to look for small interference effects in the decay of para- and orthotritium. Interactions leading to Fermi selection rules show no difference between the two. Those leading to Gamow-Teller rules show a difference between the beta-spectra of para- and equilibrium tritium which is most pronounced at low electron energies. When plotted against electron momentum, the percentage difference in the spectra resembles a damped sinusoidal function; the first three minima in the curve lie at -1.7 percent for 0.11-kv electrons, -0.6 percent for 0.68 kv and -0.3 percent for 1.7 kv, and the two intervening maxima are $+0.8$ percent and $+0.4$ percent. This is

probably much too small to be measured at present. The integrated effect on the number of He^3 nuclei produced cancels out almost completely because of the oscillation. The effect of the change in spacing and in the spring constant of the molecule because of low order rotations is shown to be negligible.

B2. The Gamma-Alpha-Reaction in Cu^{65}. R. N. H. HASLAM, L. A. SMITH, AND J. G. V. TAYLOR, *Betatron Group, University of Saskatchewan.*—Co^{61} has been produced by the (γ, α) reaction in Cu^{65} with the University of Saskatchewan betatron, and separated chemically from copper and nickel. Higher activities than previously reported have been obtained, allowing accurate determination of half-life and energy. The half-life is found to be 1.642 ± 0.003 hours, which is considerably lower than the literature values.[1-3] The β^- energy appears to be somewhat higher than the reported value of 1.3 Mev.[3] More accurate determinations will be carried out. Cross-section curves are being prepared. At corresponding energies the cross section is an order of magnitude greater than that reported by this laboratory[4] for $Rb^{77}(\gamma, \alpha)Br^{33}$.

[1] M. L. Perlman and G. Friedlander, Phys. Rev. **74**, 442 (1948).
[2] Parmley, Moyer, and Lilly, Phys. Rev. **75**, 619 (1949).
[3] H. H. Hopkins, Jr., and B. B. Cunningham, Phys. Rev. **73**, 1406 (1948).
[4] R. N. H. Haslam and H. M. Skarsgard, Phys. Rev. **81**, 479 (1951).

B3. Gamma-Neutron Cross Sections for N^{14} and O^{16}. R. J. HORSLEY, H. E. JOHNS, AND R. N. H. HASLAM, *Betatron Group, University of Saskatchewan.*—Activation curves for (γ, n) reactions in N^{14} and O^{16} have been obtained by irradiating NH_4NO_3 with x-rays from the University of Saskatchewan betatron. The two-minute oxygen activity was separated from the ten-minute nitrogen activity by an analysis of the decay curve. Cross-section curves will be presented. The nitrogen activity shows a slowly increasing initial portion from a threshold at 10.8 to a peak at 21.5 Mev.

B4. Two-Dimensional Pulse Height Presentation for Scintillation Spectrometry.* R. F. POST, *Stanford University.*—An oscillographic method has been devised for the presentation of the correlated pulse heights from coincident scintillation counts in two separate counters. The device described uses a cathode-ray tube[1] to present a cartesian plot of scintillation pulses as bright dots, the coordinates of which are proportional to the respective energies lost in the two crystals. Such a presentation, photographed, possesses features desirable for coincidence spectrometry. For example, the loci of events of constant *total* energy are diagonal lines. Utilizing this property of the plot, a two-crystal gamma-ray spectrometer[2] with high counting efficiency has been constructed. Presentation is accomplished by applying the count pulses to the x and y oscilloscope axes, respectively. A short pulse is applied to the intensifier grid, timed at the x-deflection maxima. Coincidences (within the intensifier pulse length) appear as bright dots (since dx/dt and $dy/dt \approx 0$). Near-coincidences appear as faint line segments ($dy/dt \neq 0$). The method is also being used in a pair-spectrometer to investigate pair-production by high energy electrons. Its utility for other experiments will be discussed.

* The work reported herein was performed under a contract between Stanford University and the ONR.
[1] H. Kallman and C. A. Ricardo, Rev. Sci. Instr. **21**, 48 (1950), seem to have been the first to use an oscilloscope for coincidence counting.
[2] R. Hofstadter and J. A. McIntyre, Phys. Rev. **78**, 619 (1950).

B5. Molded Noncrystalline Phosphors for Scintillation Counters. J. L. HORWOOD AND G. G. EICHHOLZ, *Radioactivity Division, Department of Mines and Technical Surveys, Ottawa.*—The scintillation properties of some noncrystalline phosphors have been investigated with gamma-rays from Co^{60} and RaC. The phosphors were prepared by moulding mixtures of polystyrene and anthracene, terphenyl, and other organic substances. Stable operating conditions were deduced from pulse height distribution curves for different compositions and counting volumes. The phosphors were compared with anthracene and sodium iodide crystals and liquid phosphors, and their emission spectra were obtained. No essential differences have been observed between dispersed systems and true solid solutions; however, no catalysts[1] were employed in preparing the samples. Some applications to measurements with large-area sources of low activity will be discussed.

[1] M. G. Schorr and F. L. Torney, Phys. Rev. **80**, 474 (1950).

B6. A High Resolution Coincidence Counting System.* N. S. SHIREN AND R. F. POST, *Stanford University.*—A coincidence system, having an intrinsic resolving time of 2×10^{-10} second, and developed for use with pulsed accelerators, will be described. The circuit is based on techniques originated by others.[1,2] Output pulses from two photomultiplier tubes are presented in the X and Y axes of a DuMont K-1032 cathode-ray tube. The beam spot is intensified by a pulse bracketing the accelerator pulse. The oscilloscope screen is masked except for a rectangular opening. Coincident pulses appear as loops originating from one corner of the rectangle. Diagonal spot positioning is used for pulse-height discrimination. The coincidences are observed by a 5819 photomultiplier. Single pulses cannot record as coincidences. Using thin stilbene crystals and pulsed 931A photomultipliers,[3] with delay line clipping, a resolving time of 7×10^{-10} second has been obtained, apparently limited by statistical effects in the crystals.[4] The system is being used in an investigation of pair production by high energy electrons from the Stanford 35-Mev electron linear accelerator.

*The work reported herein was performed under a contract between Stanford University and the ONR.
[1] H. Kallman and C. A. Ricardo, Rev. Sci. Instr. **21**, 48 (1950).
[2] R. Hofstadter and J. A. McIntyre, Rev. Sci. Instr. **21**, 52 (1950).
[3] R. F. Post and N. S. Shiren, Phys. Rev. **78**, 81 (1950).
[4] R. F. Post and L. I. Schiff, Phys. Rev. **80**, 1113 (1950).

B7. Total Cross Section of Copper for 30-Mev Photons. ARNE LUNDBY AND L. MARSHALL, *Institute for Nuclear Studies, The University of Chicago.*—Fifty-Mev bremsstrahlung from the University of Chicago betatron was collimated to 0.2-cm^2 area at 25 feet from the betatron target. It impinged on a 200-mg/cm^2 W radiator placed at the apex of a triangular pair spectrometer magnet. Electron and positron pairs produced by photons of 30 ± 3 Mev were detected by two scintillation counters placed to catch particles of equal energy. Pulses from the two counters were recorded in coincidence by a circuit of 2×10^{-9}-second resolution. The background count was found by inserting a delay of 4×10^{-8} second into one channel. Absorbers were put into the collimated bremsstrahlung beam at 20 feet from the target. In this way, the total cross section of copper for 30-Mev photons has been measured as $4.65 \pm 0.19 \times 10^{-24}$ cm^2. Measurements of cross sections of other elements and at other energies are in progress.

B8. Angular Correlation Functions for Large Values of Angular Momenta.* F. G. HESS, *University of British Columbia.* (Introduced by W. Opechowski).—Some angular correlation functions have been computed for the case that the first of the two successively emitted particles is a photon or an alpha-particle, and the second is a photon corresponding to a mixture of magnetic dipole and electric quadrupole. Explicit formulas, in terms of $\cos^2\theta$, have been obtained for an arbitrary value of the angular momentum L_1 carried off in the first transition on the assumption that the remaining angular momenta involved satisfy certain conditions, e.g., $J' = J + L_1$, $J = J'' + L_2$; $J' = L_1 - J$, $J = J'' + L_2$ (in Falkoff and Uhlenbeck's[1] notation).

* This work has been supported by the National Research Council of Canada.
[1] D. L. Falkoff and G. E. Uhlenbeck, Phys. Rev. **79**, 323 (1950).

B9. Energy Dependence of the Beta-Gamma-Angular Correlation in Sb^{124}. E. K. DARBY AND W. OPECHOWSKI, *University of British Columbia.**—Recently, Stevenson[1] briefly reported on his measurements of the energy dependence of the beta-gamma-correlation in Sb^{124}, in which he used a lens spectrometer. We have measured the same energy dependence using a twelve-channel kicksorter together with a thick crystal counter as a beta-detector.[2] The experimental curve representing the correlation coefficient (corresponding to coincidence counting rates at 90 and 180 degree) as a function of the energy seems to lie slightly higher than the values found by Stevenson, and to be not inconsistent with angular momenta assignments 1, 1, 0 (assuming the matrix element B_{ij} as dominant). We have also found that the integral correlation (beta-energy >1 Mev) is of the form $1-0.23\cos^3\theta$, in essential agreement with Beyster and Wiedenbeck.[3] This result was obtained using a thin crystal beta-counter, readings being taken at ten-degree intervals.

* This work has been supported by the National Research Council of Canada.
[1] D. T. Stevenson, Phys. Rev. **82**, 333A (1951).
[2] J. I. Hopkins, Rev. Sci. Instr. **22**, 29 (1951).
[3] J. R. Beyster and M. L. Wiedenbeck, Phys. Rev. **79**, 169 (1950).

B10. The Yield of the Reaction $C^{12}(p,\gamma)N^{13}(\beta^+)C^{13}$. J. D. SEAGRAVE, *Kellogg Radiation Laboratory, California Institute of Technology.**—The thick target yield of $C^{12}(p,\gamma)N^{13}$ has been studied from 0.45 to 2.5 Mev by observation of annihilation quanta associated with the positron decay of N^{13}. After bombardment by a fixed charge in a time short compared with the N^{13} half-life, the graphite targets were removed from vacuum, enclosed in aluminum, and placed directly over a NaI crystal and photomultiplier. The activity produced was counted with less than 1 percent random error. Only the two resonances previously reported were found. For the upper resonance[1] we find the values $E_R=1.70\pm0.008$ Mev, $\Gamma=70\pm5$ kev. The maximum thick target yield of the upper resonance is 1.45 ± 0.03 times that of the resonance at 0.45 Mev. No other resonances of intensity >2 percent appear below 2.1 Mev, or >15 percent between 2.1 and 2.5 Mev. A possible weak resonance near 2.3 Mev could not be confirmed. A measurement of the absolute yield was made with the aid of a single-channel differential analyzer, by comparison of the annihilation radiation from the N^{13} source with that from a Na^{22} source of known strength, with the result $7.7\pm0.7\times10^{-10}$ N^{13}/proton, at $E_p=1.00$ Mev, in agreement with a previous report.[2]

* Assisted by the joint program of the ONR and AEC.
[1] D. M. Van Patter, Phys. Rev. **76**, 1264 (1949).
[2] W. A. Fowler and C. C. Lauritsen, Phys. Rev. **76**, 314 (1949).

B11. Masses of Light Nuclei from Nuclear Disintegration Energies.* C. W. LI, WARD WHALING, W. A. FOWLER, AND C. C. LAURITSEN, *Kellogg Radiation Laboratory, California Institute of Technology.*—The recent accumulation of nuclear disintegration energy values makes it possible for the first time to derive the masses of light nuclei directly in terms of O^{16}, without recourse to mass spectrographic results. The masses are overdetermined by the experimental data, and some adjustment procedure must be used to determine unique mass values. The many cyclic conditions relating the overdetermined masses are used as a basis for this adjustment. Four fundamental mass differences have been calculated:

$$n-H^1=0.7824\pm0.001 \text{ Mev},$$
$$n_2+H^1-H^2=2.225\pm0.002 \text{ Mev},$$
$$2H-H^1-H^2=4.032\pm0.004 \text{ Mev},$$
$$2H^2-He^4=23.833\pm0.007 \text{ Mev}.$$

By means of these mass differences, the experimental Q-values have been adjusted by an approximate least-squares procedure to yield a numerically consistent set of adjusted Q-values and hence the values of masses. Several important atomic masses are, in amu,

$$n=1.008\ 982\ (\pm3),$$
$$H^1=1.008\ 141\ (\pm3),$$
$$H^2=2.014\ 734\ (\pm6),$$
$$He^4=4.003\ 872\ (\pm15),$$
$$C^{12}=12.003\ 803\ (\pm17).$$

Values for the 31 atomic masses from n' to F^{20} will be given. There are some discrepancies between these mass values and the most recent mass spectrographic results.

* Assisted by the joint program of the ONR and AEC.

Invited Paper

B12. The NRX Pile at Chalk River in Operation for Physics Research. W. B. LEWIS, *National Research Council, Chalk River.* (30 min.)

MONDAY AFTERNOON AT 2:00

Physics Building, Room 200

(F. A. JENKINS presiding)

Contributed Papers

C1. Ion Production by Resonance Irradiation of Hg Vapor in N_2. J. A. BERBERET AND K. C. CLARK, *University of Washington.*—Additional studies are reported on the mercury ions[1] formed in Hg vapor in the presence of N_2 by the core of the Hg resonance line $\lambda2537$. The ion current, which is proportional to the square of $\lambda2537$ intensity, is a volume effect. With extremely pure N_2 a saturation current of several hundred microamperes can be produced. In addition to the collection of ions, observations were made of the relative population of metastable Hg 6^3P_0 atoms by means of the reversal of $\lambda4047$, using various N_2 pressures up to 55 mm and the pulsed operation of either the $\lambda2537$ source or the collection voltage. By comparison of the decay rate of the ion current with that of the 6^3P_0 population, it is shown that the suggested ion formation processes involving only atoms[2] are improbable. Evidence is presented that collisions involving excited molecules of mercury[3] predominate in the ionization.

[1] W. Steubing, Physik. Z. **10**, 787 (1909). G. Giddings and G. Rouse, Proc. Natl. Acad. Sci. U. S. **12**, 447 (1926).
[2] F. Houtermans, Z. Physik. **41**, 619 (1927). F. Arnot and M. M'Even, Proc. Roy. Soc. (London) **A165**, 133 (1938).
[3] Lord Rayleigh, Proc. Roy. Soc. (London) **A114**, 620 (1927). S. Mrozowski, Revs. Modern Phys. **16**, 153 (1944).

C2. The Effect of a Magnetic Field upon the Lifetime of the Active Nitrogen Afterglow. W. R. KANE AND K. C. CLARK, *University of Washington.*—According to the theory of Mitra,[1,2] nitrogen ions, and not metastable atoms or molecules, are the carriers of energy in the Lewis-Rayleigh active nitrogen afterglow. As a test, a magnetic field was used to impede the diffusion of ions to the wall of a long glass tube of 4-inch diameter, in which decay occurred chiefly at the wall. The afterglow was produced by a disruptive electrodeless discharge, which was cut off just before the magnetic field was turned on. The decay of the afterglow intensity was recorded photographically by means of a 1P22 photomultiplier tube and oscilloscope. Decay times of the order of 0.07 second were observed at a pressure of 0.017 mm. A total of 95 runs was made, with the field alternately on and off. A field of 850 gauss was found to reduce the decay rate by 2.9 ± 0.5 percent. This effect is approximately that redicted on the basis of kinetic theory and helps to substantiate the Mitra theory.

[1] S. K. Mitra, *Active Nitrogen—A New Theory* (Indian Assoc. Advancement Sci., Calcutta, 1945).
[2] S. K. Mitra, Phys. Rev. **74**, 1637 (1948).

C3. White Mountain Research Station. CHARLES L. D'OOGE, *U. S. Naval Ordnance Test Station* (Introduced by F. T. Rogers, Jr.).—In the autumn of 1948 a high altitude observatory was established at 10,600 feet in the White Mountains of California in response to suggestions of scientists in California. Two and one-half years of continuous operation have proved the accessibility and usefulness of the site. A description of the location, weather, and facilities is presented with a general comparison to other mountain stations in the country. Weather observations (including those for three winter seasons) show that the White Mountain Research Station enjoys the distinction of being the driest, most clement mountain station available. Temperatures for the period of operation have ranged from 75° to −19°F (with winter means of 17° to 28°F and a summer mean of about 45°F), relative humidity averages 50 percent, yearly precipitation averages about 11 inches, and the winter season's snowfall ranges from 138″ the first winter to 43″ the past winter. Clear and partly cloudy days outnumber cloudy days about three times. The location on a plateau area from 10,000 to 14,242 feet in elevation has proved ideal for investigations of cosmic radiation, solar and sky radiation, light of the night sky, sky brightness, and meteorological phenomena.

C4. Atmospheric Absorption of Solar Infrared Radiation. ROMUALD ANTHONY, *U. S. Naval Ordnance Test Station, Inyokern.*—Some observations of solar infrared radiation from 1.5μ to 20μ were made from Table Mountain, California. After correction for slit width and dispersion, the recorded deflections for given wavelengths between 7.4μ and 19μ were plotted to determine the absorption coefficient, α_ν, from the equation $I_\nu = I_{\nu 0}\exp(-\alpha_\nu \ell)$ as well as the shape of the curve. The coefficient α_ν was then plotted against frequency in cm^{-1}. In the region $\nu = 1150$ to 800 cm^{-1}, this curve was found to lie below the values obtained from Elsasser's[1] approximation. Comparison of $I_{\nu 0}$ in the above equation with the form of experimental curve of infrared solar radiation obtained at 37,000 feet altitude showed a marked difference.

[1] W. M. Elsasser, Phys. Rev. **53**, 768 (1938).

C5. On the (OI) Airglow in the Night Sky.* EDWARD V. ASHBURN AND DOROTHY DAVIS LOCANTHI, *U. S. Naval Ordnance Test Station, Inyokern.*—Photoelectric observations of the forbidden oxygen line at 5577A for one night are discussed. In general, each point in the sky has a pronounced maximum in intensity shortly after midnight. The sky was relatively brightest toward the southeast during midnight and relatively brightest toward the north after midnight. The height and movement of the apparent bright patches are discussed.

* The project was supported by a research grant from the ONR Project NR-082-045.

C6. Photoelectric Measurements of the Red and Green Auroral Lines. C. DAHLSTROM, D. HUNTEN, AND W. PETRIE, *University of Saskatchewan.*—Equipment consisting of a 1P21 photomultiplier tube, an ac amplifier, and an Esterline-Angus recorder have been used to measure the intensities of the forbidden OI lines at 5577, 6300, 6364 angstroms in auroral displays. The three radiations are fed into the photomultiplier through the use of interference filters, or, alternatively, a three-prism spectrograph. The results to date indicate that in steady displays the three energy levels involved are in a state of equilibrium, and an analysis of the intensities suggests that the excitation mechanism is not collisional in nature. Some other mechanism such as dissociative recombination must be operating.

C7. Spectrographic Survey of the Night Sky at College, Alaska.* L. HERMAN† AND H. LEINBACH, *University of Alaska.*—A spectroscopic survey of the night sky beginning in late November, 1950, reveals no time at which auroral phenomena is totally absent and that at times visual observation shows no evidence of the aurora. Characteristic auroral emissions are present at all times and can be photographed on moonlit and cloudy nights. Thus, auroral activity could be followed in all weather.

* The research reported in this paper has been made possible through the support and sponsorship extended by the Geophysical Research Directorate of the Air Force Cambridge Research Laboratories under contract AF 19(122)-431.
† On leave from the University of Paris.

C8. Absolute Absorption of O_2 in the Vacuum Ultraviolet. G. L. WEISSLER* AND PO LEE, *University of Southern California.*—Absorption coefficients of radiation between 300 and 1300A were measured in O_2, using photometric techniques with a constant intensity line emission source. Lambert's exponential law of absorption was shown to be obeyed for the O_2 pressures used. The coefficients near 1300A were less than 10 cm^{-1}. No strong continuous absorption was found in the region between 1300A and 740A. However, the bands in this range showed strong absorption, of the order of 500 cm^{-1} to 800 cm^{-1}. The strong continuous absorption below 740A had a maximum coefficient of $k = 900$ cm^{-1} at about 450A and showed still a $k = 530$ cm^{-1} at 303A. This continuum was interpreted as composed of the ionization continua of several Rydbert series converging to the excited states of the molecular ion, such as $O_2^+ b\,{}^4\Sigma^- \leftarrow O_2 X\,{}^3\Sigma_g^-$. An estimate of the integrated absorption coefficients was made and an approximate f-value of six was found in agreement with predictions from dispersion data. The k-values for 76 wavelengths will be presented.

* The aid of ONR is gratefully acknowledged.

C9. Isotope Shift in the Atomic Spectrum of Oxygen.* JOHN R. HOLMES AND LEE W. PARKER, *University of Southern California.*—Isotope shift has been measured in some of the visible and infrared lines of a mixture of O^{16} with about 20 percent O^{18} (kindly given by A. O. Nier). A mixture of about 5 mm of helium and 0.5 mm of oxygen was excited in an electrodeless quartz discharge tube immersed in liquid nitrogen. The oxygen lines emitted from this source were strong compared with the band background and intense enough to be conveniently photographed through a Fabry-Perot interferometer in series with a large prism spectrograph. The patterns were sufficiently sharp for the component due to O^{18} to be resolved clearly in several lines. Microdensitometer traces were taken of some lines, from which the isotope shift

was measured by fitting the positions of the peaks to a second degree interpolation equation, while for lines which were very close to adjacent lines the isotope shift was measured on a micrometer. The results are as follows:

Wavelength	Transition	Isotope shift
8820.45A	$3s'^1D_2^0-3p'^1F_3$	$+0.1088 \pm 0.001$ cm^{-1}
8221.84	$3s'^3D_3^0-3p'^3D_{3,2}$	$+0.0830 \pm 0.0015$
8232.99	$3s'^3D_1^0-3p'^3D_1$	$+0.08305 \pm 0.002$.

These lines occur in the displaced (^3D) system. In fifteen lines of the normal (^4S) system occurring as transitions between quintet levels no isotope shift was found.

* Work supported by the ONR.

C10. Electron Drift Velocities at Low X/p. W. N. ENGLISH,* *Chalk River Laboratory.*—Electron drift velocities have been measured as a function of electric field divided by pressure in the range 0.05 to 0.5 volt per cm per mm Hg. A plane parallel electron pulse chamber (with grid) was used, with collimated alpha-particle source mounted on the cathode. Electron drift velocity within 10 percent is obtained from the known length of alpha-track divided by the rise time of the pulse measured with a fast amplifier and oscilloscope. Data have been obtained for argon plus CO_2, 1 percent to 20 percent, and cp tank methane. Results in argon$-CO_2$ agree with Rossi and Staub. The methane gives the surprisingly high value of 8 cm/μsec at $X/p=0.5$, compared with 4.5 cm/μsec for the fastest argon$-CO_2$ mixture. Preliminary measurements in hydrogen agree with the published results of Bradbury and Nielson. A study of electron pulse amplitude *vs* X/p is also being made to obtain information on electron attachment to impurity atoms in free-electron gases.

* Now at Pacific Naval Laboratory, Esquimalt, B. C.

Invited Paper

C11. The Geophysical Institute, A Center for Research in the Arctic. WILLIAM S. WILSON, *University of Alaska.* (30 min.)

TUESDAY MORNING AT 9:00

Physics Building, Room 200

(S. E. MADDIGAN presiding)

Contributed Papers

D1. Mistuning Contributes to Tone Quality. EDWARD M. LITTLE, *University of Alaska.*—It is generally believed that the quality of a musical tone is determined by the strength of its harmonics. The quality is really not affected by the pitch vibrato on theater organs or the volume tremulant on concert and church organs. However, organists have known for hundreds of years that two ranks of pipes mistuned about .1 semitone with respect to each other—the celeste effect—add subtle warmth to the tone quality of chords, quite unlike the effect of vibrato or tremulo in which all tones vary synchronously. This explains why the quality of a chorus is much better than that of a quartet; the unavoidable differences in frequencies cause beats whose frequencies are roughly proportional to the frequencies of the notes, producing a delightful scintillation of tone quality, as all the notes of a chord beat at their own different rates. Experiments have been performed to find the optimum mistuning for each note of a diad. This may be demonstrated on a ukulele. This is to be extended to triads (chords), and also more than 2 notes beating. In the world's largest organ in the Wanamaker store, one celeste stop has 10 ranks of pipes!

D2. Emission of Electrical Influence. F. W. WARBURTON, *University of Redlands.*—Expansion of the coulomb electrical energy of two charges e' and e in terms of the time of propagation from e' to e together with a factor assumed to represent the manner in which e receives the emission from e', yields electric and magnetic potential energy, $W=ee'[1/r+(\mathbf{u}\cdot\mathbf{r})^2/2c^2r^3-\mathbf{g}\cdot\mathbf{r}/2c^2r+\cdots]$, where $\mathbf{u}$ is the relative velocity and $\mathbf{g}$ the relative acceleration of e' and e. The average negative gradient of this potential energy yields the reciprocal force discussed earlier.[1] This is one of the many formulas which correctly express the behavior of electric circuits and which have the advantage over standard theory of expressing the induced electric field of accelerated charges explicitly. Besides accounting for gyromagnetism by recognition of magnetic potential energy, and suggesting a stable electron, this energy formula provides description of energy transfer associated with accelerating an electron.

[1] F. W. Warburton, Phys. Rev. **69**, 40 (1946); **72**, 747 (1947).

D3. Phenomena Associated with the Flight of Ultra-Speed Pellets.* Part I: Ballistics. WILLIAM A. ALLEN, JOHN S. RINEHART, AND W. C. WHITE, *U. S. Naval Ordnance Test Station, Inyokern.*—Small metallic pellets have been fired at velocities up to 6 km/sec by means of modified shaped charges. Previous work in this field has been confined largely to observations of meteors and conventional shaped charges. Data obtained on ballistic phenomena verify the conventional drag force determinations extrapolated to large Mach numbers. Steel pellets at a velocity of 2.5 km/sec lose little mass in flight. Pellets composed of lighter metals, such as aluminum at a velocity of 5.0 km/sec, burn vigorously with the emission of much light and heat. It has been found that the motion of both non-burning and burning pellets can be represented within experimental error by the empirical equation, $v=v_0e^{-\alpha s}$, where v_0 is the initial velocity of the pellet, v is its velocity after it has traveled a distance s through the air and α is a constant.

* Work supported by Armament Branch, ONR.

D4. Phenomena Associated with the Flight of Ultra-Speed Pellets.* Part II: Spectral Character of Luminosity. W. C. WHITE, JOHN S. RINEHART, AND WILLIAM A. ALLEN, *U. S. Naval Ordnance Test Station, Inyokern.*—The spectroscopic character of the luminous trails generated by ultra-speed pellets has been investigated. A total of seven spectrograms have been measured and reduced. Three of these were of 5.0 km/sec aluminum pellets; two were of 5.9 km/sec magnesium pellets; one was of a 6.0 km/sec magnesium-aluminum-lithium pellet and one was of a titanium pellet whose velocity

was estimated at about 4.5 km/sec. The most pronounced features of the spectrograms are: (1) AlO bands in the aluminum spectra, (2) Mg lines and MgO bands in the magnesium spectra, (3) strong Li lines and a pronounced continuum in the magnesium-lithium-aluminum spectra and (4) TiO bands in the titanium spectra. Other features of the spectra are: (1) prominent Al I lines at λλ3944 and 2961 and a relatively weak continuum in the aluminum spectra, (2) a stronger continuum in the magnesium spectra and (3), relatively weak MgO bands in the Mg-Li spectra. The time resolved spectra show that the AlO persists in the excited state twice as long as the aluminum. The aluminum oxidizes almost completely leaving AlO in an excited state which continues to emit light after the aluminum is burned.

* Work supported by Armament Branch, ONR.

D5. Phenomena Associated with the Flight of Ultra-Speed Pellets.* Part III: General Character of Luminosity. JOHN S. RINEHART, WILLIAM A. ALLEN, AND W. C. WHITE, *U. S. Naval Ordnance Test Station, Inyokern.*—Ultra-speed pellets of the lighter metals such as aluminum and magnesium have intensely luminous trails associated with their flight through the air. A pronounced characteristic of the luminous trails is the *intermittent* manner in which the luminosity is generated. This effect has also been observed in meteors[1] and in studies of conventional shaped charges.[2] The brilliant flashes of light appear to be associated with the ablation and subsequent burning of material from the pellet. There is considerable evidence that the material is removed from the pellet in the form of small droplets. Luminous shock waves are also observed but this source of light contributes little to the total. Stereoscopic photographs indicate that the pellet may follow a more or less sinusoidal path or spiral through the air. Flashing seems to be associated with the maximum amplitude of the motion.

* Work supported by Armament Branch, ONR.
[1] W. W. Zimmerman and C. R. Hammond, Contr. Soc. Research Meteorites **2**, 2, 73 (1939); Harvard Coll. Obs. and Center of Analysis of M.I.T. Tech. Rept. **3**, 22 (1949).
[2] J. S. Rinehard, Rev. Sci. Instr. **21**, 939 (1950).

D6. Viscosity, Molecular Shape and Microwave Absorption in Solution. P. L. MCGEER, G. B. RATHMANN, A. J. CURTIS, AND C. P. SMYTH, *Princeton University.*—Measurements of dielectric constant and loss at wavelengths of 1, 3, and 10 cm over a temperature range from 4 to 60° have been carried out upon dilute solutions of polar molecules in *n*-heptane and a viscous paraffin oil. An almost thousand-fold variation in viscosity was achieved with the two solvents over the temperature range investigated. The change in relaxation time for the dipole orientation process over this viscosity range reached a maximum of only 15-fold for the long tetradecyl bromide molecule and was much smaller for the nearly spherical molecules of *t*-butyl chloride and methyl chloroform, which could rotate with little or no displacement of the surrounding solvent molecules. The relaxation times of the large and unsymmetrical molecules of α-chloronaphthalene and tetradecyl bromide are more affected by viscosity, because the orientation of their dipoles requires the displacement of the surrounding solvent molecules. A distribution of relaxation times was observed in these solutions, greater for the more viscous solvent. Possible reasons for the distribution would be orientation of the molecules by rotation about different axes, orientation of molecular segments, and thermal fluctuations.

D7. Studies of Thin Films by Electron Diffraction. N. R. MUKHERJEE AND OLIVER ROW, *Engineering Experiment Station, University of Washington* (Introduced by Professor C. L. Utterback).—Thin films of metals were prepared by evaporation on soluble plastic. Assuming that the entire sample was evaporated into a spherical space, the thickness of the film was calculated by inverse square law from the knowledge of the quantity of metal evaporated in each case. The substrate was dissolved and samples made out of free metallic films were studied with the electron diffraction camera. In all cases it is found that an optimum thickness exists at which a transmission diffraction pattern of any metal shows a greater number of rings, sharper rings and a better contrast between the rings and the background. The optimum thickness of the film appears to be an inverse function of density of the substance.

D8. Energy Loss of Shock Waves to Cloud Water Droplets. RICHARD L. MOORE,* *Sandia Corp. and Armed Forces Special Weapons Project.*—The break-up and subsequent evaporation of water droplets by a shock wave removes energy from the shock. At a certain radius (R_e) from the center of a spherical wave the radius (a_e) of the largest droplet remaining after passage of the shock front is just equal to the radius of the largest drop which can be evaporated by the shock. a_i is the initial radius of the droplet; $f(a_i)$ is the initial[1] frequency distribution of a_i. The assumptions involved will be stated and development will be made of the ratio of the energy lost outside R_e to that lost inside, which is:

$$\frac{E_0}{E_e}=\frac{3}{(a_i)^3}\left[\int_{x=1}^{x_1}x^2\left(\int_{a_i=0}^{a_e x^{-\frac{1}{3}}}(a_i)^3 f(a_i)da_i + \int_{a_e x^{-\frac{1}{3}}}^{a_e x^{2.9}}(a_i)^3\left(1-\left(1-\left(\frac{a^s}{a_i}\right)^3 x^{-1}\right)^{\frac{1}{3}}\right)f(a_i)da_i + \int_{a_e x^{2.9}}^{\infty}(a_i)^3(1-(1-x^{-0.9})^{\frac{1}{3}})f(a_i)da_i\right)dx\right].$$

The results** will be given as a function of the limits of $x=R/R_e$; of a_e; and of $f(a_i)$ in four types of clouds.

* Major, USAF.
[1] H. J. aufm Kampe, J. Meteorol. **7**, 54 (1950).
** Numerical evaluation of integrals completed by Test Data Division of Sandia Corporation.

D9. Analysis and Behavior of Some Magnetic Amplifier Circuits. HOWARD A. WILCOX, *Naval Ordnance Test Station, Inyokern.*—The magnetic amplifier is a set of saturable reactors in combination with an alternating power source whose function is to deliver either direct or alternating current to a load in the power circuit under the control of a small direct current in the control circuit. As such it becomes a direct coupled current amplifier capable of high gain, low drift, extreme ruggedness and reliability, and high over-all power efficiency. Many different magnetic amplifier circuits are known. Principles of approximate circuit analysis will be presented, together with the analyses of four basic magnetic amplifier circuits, namely the series and parallel connected circuits, with and without feedback. A detailed comparison between the analytical predictions and actual performances of the circuits will be given.

D10. Sources of Energy Degradation and Side Thrust in Laval Rocket Nozzles. A. B. C. ANDERSON AND H. W. WEDAA, *U. S. Naval Ordnance Test Station* (Introduced by F. T. Rogers, Jr.).—Results of an experimental survey of the effect of the placement of obstructions in the input side of a Laval nozzle on side-thrust and energy degradation are reported. Work was carried out using a 2-dimensional nozzle and nitrogen. Extremely small differential pressures between opposite sides of the nozzle were produced by the presence of huge unsymmetrical obstructions. Energy degradation in the gas flow, here, is measured by the departure of the experimentally observed pressure distribution from the theoretical, adiabatic; isentropic pressure distribution. Degradation due to wall friction is manifested, on the subsonic side, by a drop in the pressure distribution, on the supersonic side, by a rise in the pressure distribution with respect to the theoretical distribution. Physically, this degradation may be interpreted in terms

of the formation of a boundary layer. Results indicate that even a thick boundary layer on the subsonic side of the nozzle is squeezed to practically zero at the throat. A new boundary layer downstream of the throat appears to begin at the throat. Degradation due to the presence of the obstacles in the flow appears to be surprisingly small. Only when the flow channel created by the obstacle becomes smaller than the nozzle throat does the degradation become quite appreciable. This appears to be due to the creation of shock waves between the obstruction and the nozzle throat.

Invited Paper

D11. The Scattering of Light Nuclei. JOHN H. WILLIAMS, *University of Minnesota.* (30 min.)

TUESDAY AFTERNOON AT 2:00

Physics Building, Room 200

(G. M. SHRUM presiding)

Contributed Papers

E1. Li^7 Nuclear Electric Quadrupole Interaction in Crystalline $LiAl(SiO_3)_2$.* D. W. SMELLIE† AND H. E. PETCH,‡ *University of British Columbia* (Introduced by G. M. Volkoff).—Using an oscillating detector, the splitting of the nuclear magnetic resonance absorption line due to electric quadrupole coupling[1] has been observed for the Li^7 resonance in a single crystal of spodumene ($LiAl(SiO_3)_2$). The dependence of this splitting on the angle between the magnetic field and the *b*-axis has been measured in a plane perpendicular to the *c*-axis of the monoclinic structure. A discussion of the experimental results and their theoretical interpretation will be presented.

* Work supported by the National Research Council of Canada.
† Holder of a National Research Council Bursary.
‡ Holder of a Fellowship from the Research Council of Ontario.
[1] R. V. Pound, Phys. Rev. **79**, 685 (1950).

E2. Nuclear Spin of Selenium 77. SUMNER P. DAVIS AND F. A. JENKINS, *University of California, Berkeley.*—Previous evidence on the spin of Se^{77} is conflicting, hyperfine structure indicating $I>5/2$ and microwave spectra $I=1/2$. In order to decide the question, alternating intensities in the rotational structure of the ultraviolet bands of Se_2^{77} have been investigated. The source was a radiofrequency discharge in a small quartz tube containing a rare gas and a few milligrams of enriched selenium. This source is capable of yielding a band spectrum with as little as 2 μgm of the nonmetallic elements. High dispersion spectrograms have been obtained of 58.4 percent Se^{77}, and a detailed analysis of the 10.4 and 10.5 bands made. The Se_2^{77} bands show a pronounced intensity alternation, with the lines of odd K stronger. Overlapping by lines because of other species, principally $Se^{77}Se^{80}$, prevents an accurate measurement of the alternation ratio, but it appears to be large enough to exclude the higher value of I. Through the cooperation of the Oak Ridge laboratory, a sample containing 91.8 percent of Se^{77} is now available. By its use, it will probably be possible to give a definitive result at the time this paper is presented.

E3. The Neighboring Mirror Nuclei Ne^{11} and Na^{21}. GLEN E. SCHRANK AND J. REGINALD RICHARDSON, *University of California at Los Angeles.**—Ne^{19} and Na^{21} are neighboring mirror nuclei with a considerable difference in their ft values. A more detailed examination of their positron spectra and lifetimes seemed to be desirable. The presence of gamma-radiations[1] in the 1.5-Mev energy range from Na^{21} has been verified by the use of a NaI crystal gamma-ray spectrometer. The Ne^{19} isotope was produced by the (p, n) reaction on fluorine (BaF). The Na^{21} was produced by the (p, α) reaction on magnesium. The positron spectra were examined in a 180° beta-ray spectrometer and the upper limits were determined from Kurie plots. The results indicate an upper limit of 2.16 Mev for Ne^{19} and 2.50 Mev for Na^{21} with an uncertainty of one percent. There is evidence for the presence of a lower energy positron group in Na^{21}. The lifetimes obtained are 18.5 seconds for Ne^{19} and 22.8 seconds for Na^{21}. The difference in ft values for these two nuclei would therefore appear to be real, and not the result of experimental inaccuracies.

* This work was supported in part by the joint program of the ONR and AEC.
[1] E. Pollard and W. W. Watson, Phys. Rev. **58**, 12 (1940).

E4. The Radiations from K^{38}. DAVID GREEN AND J. REGINALD RICHARDSON, *University of California at Los Angeles.**—A large beta-ray spectrometer of the double lens type has been used to investigate the radiations from K^{38}. The isotope[1] under investigation was formed by the bombardment of KI with 18-Mev protons. The reaction involved is (p, pn). Because of the short lifetime for K^{38}, small crystals of KI are bombarded directly and then mounted on Nylon foils for measurement in the spectrometer. The purity of the activity is demonstrated by its measured time variation which gives a straight line when plotted in the usual way over a time corresponding to six half-lives. The half-life obtained is 7.7 minutes. The Kurie plot of the upper part of the positron spectrum yields an upper energy limit of 2.8 Mev. The gamma-radiation from this isotope is also being investigated.

* This work was supported in part by the joint program of the ONR and AEC.
[1] Ramsey, Meem, and Mitchell, Phys. Rev. **72**, 639 (1947).

E5. Use of the Rosenblum Spark Counter for Alpha-Counting. G. G. EICHHOLZ, *Radioactivity Division, Department of Mines and Technical Surveys, Ottawa.*—The properties of a simple spark counter of the Rosenblum type similar to that of Payne[1] and Connor[2] has been investigated. The system proved both rugged and reliable and for a collimated polonium source specific ionization curves were obtained which showed no more straggling than a shallow ionization chamber. The voltage characteristics of the counter differed somewhat from those of Connor. An interesting property of these counters is the effect of self-stabilization due to the corona discharge. Results of measurements on various radioactive powders will be discussed and the relative efficiency of these counters compared with other alpha-particle detectors.

[1] R. M. Payne, J. Sci. Instr. **26**, 321 (1949).
[2] R. D. Connor, Proc. Phys. Soc. (London) B. **64**, 30 (1951).

E6. Disintegration of 70-Day Ir^{192}. W. W. SCHOOF* AND R. D. HILL, *University of Illinois*.†—The internal conversion electron spectrum of long-lived Ir^{192} has been investigated previously by Levy,[1] Cork[2] and Hill and Meyerhof.[3] Using a 180° variable field spectrometer with a resolution of approximately 2 percent, we have identified gamma-ray lines of the following energies: 137, 208, 295, 308, 317, 469, 488, 592, 607, and 615 kev. In attempting to construct a level scheme of the gamma-ray emitting Pt^{192} nucleus, we have measured the intensities of the above transitions. From the electron spectrum, the relative total conversion electron intensities are, respectively: 7.5, 10, 35, 30, 100, 25, 2.0, 2.5, 2.5, 4.0. From the photo-electron spectrum, the gamma-ray intensities are, respectively: 45, 5, 35, 15, 100, 75, <10, <15, 20, 20. Although a number of energetically possible level schemes, which give rise to all gamma-rays, can be constructed, it is still impossible on the basis of the above intensity values to decide on a unique level scheme. Either a decomposition of the partial beta-ray spectra of Ir^{192} or an investigation of coincident transitions appears to be further required.

* Now at Boeing Airplane Company, Seattle, Washington.
† Assisted in part by the joint program of the ONR and AEC.
[1] P. W. Levy, Phys. Rev. **72**, 352 (1947).
[2] J. M. Cork, Phys. Rev. **72**, 581 (1947).
[3] R. D. Hill and W. E. Meyerhof, Phys. Rev. **73**, 812 (1948).

E7. The Solution of X-ray Activation Curves for Photonuclear Cross Sections. A. G. W. CAMERON AND L. KATZ, *University of Saskatchewan*.—Johns *et al.*[1] have recently published graphs of the Schiff bremsstrahlung intensity in the forward direction as functions of the photon and betatron energies, normalized to 100 roentgens measured in Lucite. They used these curves to calculate a number of (γ, n) cross-section curves from the corresponding x-ray activation curves. A modification of this method is proposed which is based on the photon differences between successive Schiff bremsstrahlung curves and the first derivative of an activation curve. It is required that the first and second derivatives be smooth; this requirement has been empirically justified. Tables of suitable computational functions have been prepared. The activation curves measured in this laboratory have been reanalyzed by this "photon difference" method, and the resulting curves were found in good agreement with those originally calculated. The new method avoids the necessity for arbitrary progressive smoothing of a cross section curve during computation, and effects a large reduction in the time required for such a calculation.

[1] Johns, Katz, Douglas, and Haslam, Phys. Rev. **80**, 1062 (1950).

E8. Photonuclear Cross Sections in Aluminum and Magnesium. L. KATZ AND A. G. W. CAMERON, *University of Saskatchewan*.—Activation curves for the reactions $Al^{27}(\gamma, n)Al^{26}$, $Mg^{24}(\gamma, n)Mg^{23}$, and $Mg^{26}(\gamma, p)Na^{25}$ have been measured using "swing" and "dropping" techniques for the rapid transfer of a sample from the betatron irradiation position to a counter. Absolute ordinates were determined by comparison to the known $Cu^{63}(\gamma, n)Cu^{62}$ activity at 22 Mev, and the corresponding cross sections were computed by the "photon difference" method.[1] The cross-section curves exhibited "resonance" peaks characteristic of photonuclear reactions. Preliminary values for the peak energies, peak cross sections, widths at half-maximum, and integrated cross sections of these curves are

$Al^{27}(\gamma, n)Al^{26}$	19.2 Mev	0.0082 barn	4.7 Mev	0.045 Mev-barn
$Mg^{24}(\gamma, n)Mg^{23}$	19.4	0.0111	5.8	0.064
$Mg^{26}(\gamma, p)Na^{25}$	22.6	0.0218	3.3	0.096

The (γ, p) cross section is larger than those of (γ, n) reactions in this part of the periodic table, and the peak is at a higher energy. This suggests that high energy photons interact primarily with nuclear protons. We hope to report also the cross section curve for the reaction $Mg^{25}(\gamma, p)Na^{24}$.

[1] See preceding abstract, E7.

E9. Photoneutron Cross Sections for the Reactions $Mo^{92}(\gamma, n)Mo^{91}$ and $Mo^{92}(\gamma, n)^{91}$. R. MONTALBETTI AND L. KATZ, *University of Saskatchewan*.—Samples of molybdenum were irradiated in the betatron x-ray beam and the resulting 15.5-min (isomeric state) and 65-sec (ground-state) activities in Mo^{91} studied. The threshold for the reaction leading to the isomeric state was found to be 13.2±0.2 Mev and that of the ground state 0.1±0.1 Mev lower. This casts some doubt on the decay energies of Mo^{91} and Mo^{91*} as published by Hanson *et al.*[1] Cross sections for each of the above reactions as a function of energy were obtained by analyzing the yield curves by the photon difference method.[2] They exhibited the usual "resonance" shape peaking at 18.7 Mev. Normalization against $Cu^{63}(\gamma, n)Cu^{62}$ activity at 23 Mev gave a peak cross section of 0.030 barn for $Mo^{92}(\gamma, n)Mo^{91}$ (65 sec) and 0.145 barn for $Mo^{92}(\gamma, n)Mo^{91*}$ (15.5 min). The integrated cross sections for these reactions are 0.18 Mev-barn and 0.87 Mev-barn respectively. The ratio of the 65-sec to the 15.5-min cross sections remained quite constant above 15.5 Mev. Below this energy the ratio increased rapidly, becoming very large as the threshold for the 15.5-min activity was approached.

[1] Hanson, Duffield, Knight, Diven, and Palevsky, Phys. Rev. **76** 578 (1948).
[2] Cameron and Katz, see accompanying abstract, E7.

E10. Mercury Isotopes Produced in Gold by High Energy Protons. J. H. MOON* AND A. L. THOMPSON, *McGill University*.—The internal proton beam of the 82-in. McGill synchrocyclotron has been used to bombard gold foils. The mercury isotopes produced were separated and investigated in a thin lens beta-ray spectrometer. The gold and platinum daughter activities were used to identify the mercury isotopes as Hg 196, 195, 193, 192, 191 which appeared successively as the proton energy was increased. No indication of Hg 194 was found. All the mercury isotopes investigated decayed by *K*-capture with the emission of many, highly internally-converted, low energy γ-rays. The following information was obtained:

Isotope	Hg 195	Hg 913	Hg 192	Hg 191	Au 191
Half-life	38.0 hr	14.5 and 29.0 hr	8.4 hr	12.4 hr	18.0 hr
Proton energy	35 Mev	55 Mev	65–80 Mev	70–80 Mev	···

Threshold energies are approximately 10 Mev below those given above which give abundant yields.

* Present address: Pacific Naval Laboratory, Esquimalt, B. C.

Invited Paper

E11. Research With the 37" Cyclotron at UCLA. J. R. RICHARDSON, *University of California, Los Angeles*. (30 min.)

WEDNESDAY MORNING AT 9:00

Physics Building, Room 200

(H. GRAYSON-SMITH presiding)

Contributed Papers

F1. The Decay Scheme of Fe^{59}. K. C. MANN AND G. H. HANSON, *University of British Columbia.**—The beta- and gamma-radiations of Fe^{59} prepared by an (n, γ) process have been investigated, using a thin lens beta-ray spectrometer. In agreement with previous work,[1] two gamma-rays of approximately equal intensity were found with energies of 1.10 and 1.29 Mev, respectively. One beta-group of Mev maximum energy 0.45 Mev was found, but there was no evidence of the 0.26-Mev group previously reported.[1] A high energy (1.75 Mev) beta-group was present, but was identified as a P^{32} impurity. Neither gamma-transition showed any internal conversion. Coincidence measurements in this laboratory indicated that the gamma-rays are not in cascade. An expected 0.19-Mev gamma-ray was not detectable with the relatively high Geiger window cut-off energy and the uranium converter used, but work is continuing. The log (ft) value for the 0.45-Mev beta-transition was calculated to be 6.5, so that the transition is probably first forbidden, although the Fermi plot was straight. A tentative decay scheme is proposed.

* This work is supported by the National Research Council of Canada.
[1] M. Deutsch *et al.*, Phys. Rev. **62**, 3 (1942).

F2. The Positron Spectrum from μ-Mesons. HARMON W. HUBBARD, *University of California, Berkeley.**—The electrostatically deflected proton beam from the 184-inch Berkeley cyclotron was used to produce a π^+ meson beam.[1] The beam is brought outside the "cove" shielding through a port by means of an electromagnet. A cloud chamber in a magnet producing a field of 8000 gauss is placed in the beam. Some of the mesons stop in carbon plates situated in the cloud chamber. The decay positrons, to which the stopped π^+ mesons give rise, are subjected to measurement. Examination of the tracks, which is now in progress, indicates the spectrum to have a maximum at about 35 Mev. A careful study is being made of the shape of the spectrum near the maximum positron energy, in view of its theoretical importance.[2]

* This work was performed under the auspices of the AEC.
[1] Richman, Skinner, Merritt, and Youtz, Phys. Rev. **80**, 800 (1950).
[2] T. Tiomno and J. A. Wheeler, Revs. Modern Phys. **21**, 144 (1949).

F3. Elastic Scattering of 31.8-Mev Protons from Helium. BRUCE CORK, *University of California, Berkeley.**—Measurements have been made of the elastic scattering of 31.8-Mev protons from helium at one atmosphere. The large solid angle geometry used for proton-proton scattering[1] was used to detect the forward scattered protons. Six different increments of angle have been observed from 17° to 62° in the center-of-mass system. A plot of the differential cross section and a comparison with Rutherford scattering will be given. It is planned to detect the forward scattered α-particles and thus obtain a more complete measurement of the differential cross section.

* This work was performed under the auspices of the AEC.
[1] Cork, Johnston, and Richman, Phys. Rev. **79**, No. 1, 71–80 (1950).

F4. The Ratio of the Masses of the Positive π- and μ-Mesons. WILSON M. POWELL, *University of California, Berkeley.**—Photographs of the decay of π^+ mesons into μ^+ mesons were obtained in a cloud chamber with a magnetic field of 8200 gauss. If the meson beam is allowed to spray the top and bottom of the chamber, then occasionally very slow mesons scatter down or up into the gas of the chamber, and in a few cases π^+ mesons have been observed to come to rest before decaying. An error of 2.6 percent in the momentum of the μ^+ meson from a stopped π^+ meson gives a one percent error in the ratio of the masses. The same order of precision is possible if the π^+ meson is moving very slowly. By selecting only slowly moving π^+ mesons, individual measurements have a probable error of around three electron masses, and the value of the ratio of the masses agrees well within experimental error with that obtained by other methods.[1,2]

* This work was done under the auspices of the AEC.
[1] H. Bradner, U.C.R.L. 486 gives a summary.
[2] Smith, Barkas, Bishop, Bradner, and Gardner, Phys. Rev. **78**, 86 (1950).

F5. $C^{14}-N^{14}$ β-Decay. W. FUTTERMAN, *University of Southern California* (Introduced by E. Gerjuoy).—Theoretical lifetimes and shapes of the $C^{14}-N^{14}$ β-decay spectrum have been calculated by well-known methods,[1] assuming the parities of the ground states of C^{14} and N^{14} are different.[2] This assumption, in conflict with the usual shell model assignments, makes the transition first forbidden. The calculated lifetimes for scalar, vector, tensor, and axial interactions: $\tau_{1S}=5.35\times10^{8}$ sec, $\tau_{1A}=8.19\times10^{8}$, with τ_{1V} and τ_{1T} too much smaller than the experimental value $\tau=2.16\times10^{11}$ to warrant further consideration. If the matrix of α is assumed ≈0, without attempt at explanation, then $\tau_{1V}=4.83\times10^{8}$, $\tau_{1T}=7.44\times10^{8}$. These theoretical lifetimes are consistent with observation, assuming about 10 percent $^3S_1$ in the ground state of N^{14}, a percentage consistent with the magnetic moment.[2] When the observed spectrum[3] is plotted on a corrected Fermi plot corresponding to any of these four lifetimes, the deviation from linearity is small but probably significant. Possible mechanisms which may reduce the value of the matrix element of α will be discussed.

[1] E. Greuling, Phys. Rev. **61**, 568 (1942).
[2] E. Gerjuoy, Phys. Rev. **81**, 62 (1951).
[3] S. D. Warshaw, Phys. Rev. **80**, 111 (1950).

F6. Precision Analysis of Gamma-Ray Spectra from High Energy Proton Collisions with Nuclei. KENNETH M. CROWE, WOLFGANG K. H. PANOFSKY, ROBERT H. PHILLIPS, AND DARCY WALKER, *University of California, Berkeley.**—The gamma-ray spectra of the type measured by Bjorklund, Crandall, Moyer, and York[1] have been remeasured with the multiple channel[2] pair spectrometer previously described. The rate of data collection has been improved by the addition of a 196 coincidence pair computer. The results of these spectra, incorporation of the order of 10^5 pairs, are as follows: (1) The gamma-ray spectra from carbon and from wolfram are indistinguishable. This contradicts the results of earlier experiments which indicate that the difference in internal momenta between heavy and light elements materially affects the meson spectrum. (2) Comparison between 0° and 180° spectra makes an analysis of the spectrum into a pure π^0 effect impossible. It rather indicates that a mechanism other than bremsstrahlung and π^0 decay exists which contributes to the spectrum near 100 Mev. It is suggested that this mechanism might be production of π-mesons in one nucleon and reabsorption in another.

* This work was performed under the auspices of the AEC.
[1] Bjorklund, Crandall, Moyer, and York, Phys. Rev. **77**, 213–218 (1950).
[2] Aamodt, Hadley, and Panofsky, Phys. Rev. **81**, 565 (1951).

F7. Interpretation of (d, n) Angular Distributions.* W. HECKROTTE AND L. SCHECTER, *University of California, Berkeley.*—A continuation of the work[1] on the angular distribution of neutrons which result from bombardment by 20-Mev deuterons from the 60-inch cyclotron at Berkeley is in progress. Assignment of parities and possible spin values to the final states of the product nuclei has been extended to include the reactions $C^{12}(d, n)N^{13}$, $Co^{60}(d, n)Ni^{60}$, and $Au^{197}(d, n)^{198}$ on the basis of Butler's analysis.[2] For the $C^{12}(d, n)N^{13}$ reaction, the experimental method allows the detection of the neutrons which result from the formation of the ground state of N^{13}. On this basis, the assignment of odd parity and possible spin values of spin values of $\frac{1}{2}$, $\frac{3}{2}$ are made. This is in agreement with the shell model prediction of a $P_{\frac{1}{2}}$ state Similar information will be reported concerning the other reactions.

* This work was performed under the auspices of the AEC.
[1] Reported on at the Washington Meeting of the American Physical Society, April 26–28, 1951.
[2] S. T. Butler, Phys. Rev. **80**, 1095 (1950).

F8. A Search for an Excited He^4 Level.* J. BENVENISTE AND BRUCE CORK, *University of California, Berkeley.*—Evidence for the existence of an excited state of He^4 has been presented.[1] In this laboratory the proton linear accelerator has been used in a search for an excited level by the method of inelastic scattering of 31-Mev protons from He^4 nuclei. Laboratory angles of 30°, 45°, and 60° have been investigated by means of a telescope consisting of two gas counters in coincidence followed by an anticoincidence counter. A differential range analysis of the spectrum of scattered particles shows the elastically scattered protons and α-particles with good resolution. In addition, a third peak is observed which can, at present, here be explained as deuterons from the reaction $He^4(pd)He^3$. This peak has a differential cross section of approximately 8×10^{-27} cm^2 at 45° in the laboratory system. An upper limit for the differential cross section at 45° for the reaction $He^4(pp')He^{4*}$ (if it exists at all) is 3×10^{-27} cm^2. further investigations of particles scattered from He^4 are being made by differential energy analysis in a NaI(Ti) crystals.

* This work was performed under the auspices of the AEC.
[1] Argo, Gittings, Hemmendinger, Jarvis, and Taschek, Phys. Rev. **78**, 691 (1950).

F9. The Contribution of Protons to the Positive Excess of Cosmic Ray Particles at 3.4 Kilometers.* D. S. POTTER, GERALD GARRISON, CHARLES E. MILLER, WAYNE SANDSTROM, AND JAY TODD, JR., *Applied Physics Laboratory,† University of Washington.*—Momentum measurements were made of charged particles stopping in 15 and 30 cm of lead absorber placed under a magnetic cloud chamber. Event selection was accomplished by means of a suitable arrangement of coincidence and anticoincidence Geiger tubes. Such selection permits the separation of mesons from protons at momenta exceeding 500 Mev/c for the following two reasons: (1) the difference in the range-momentum relationships for protons and mesons in the momentum interval from 500 Mev/c to 1250 Mev/c, and (2) the nuclear interactions suffered by protons at momenta in excess of 1250 Mev/c. The proton intensities found from this spectrum are just sufficient to account for the difference between the positive and negative particle intensities for momenta less than 1000 Mev/c. At higher momenta, the proton intensity amounts to about half the difference. Thus, the positive excess at momenta less than 1000 Mev/c, obtained by this laboratory in an earlier investigation, can be completely accounted for by protons.

* Assisted by the joint program of the ONR and AEC.
† A Division of the Department of Physics.

F10. A Ten-Atmosphere Expansion Cloud Chamber with Thin Windows.* J. DEPANGHER, *University of California, Berkeley.*—The space available for the formation of tracks is a cylindrical volume of diameter 12 inches and height 2.5 inches. A $\frac{3}{4}$-inch thick Lucite cylinder backed by a $\frac{9}{16}$-inch thick perforated stainless steel cylinder make up the side wall. The perforation pattern is a compromise between strength and transparency, the latter being adequate for uniform illumination of the chamber interior as demonstrated by model tests. For photographing tracks from above, a Herculite glass cover plate is employed with diameter 13$\frac{1}{2}$ inches and thickness 1$\frac{1}{4}$ inches. Adiabatic expansion is achieved by a pantograph[1] operated Lucite piston and two expansion valves[2] which dump the gas into two expansion vessels. The entrance window is a box 16 inches long, closed at both ends by Be–Cu curved foils of 2 and 5 mil thickness. A second window is provided on the opposite side of the cloud chamber to minimize backscattering.

* This work was done under the auspices of the AEC.
[1] W. M. Powell, Rev. Sci. Instr. **20**, 403 (1949).
[2] The valves, though rectangular, are similar in principle to the valve described in the paper by R. P. Shutt and W. L. Whitmore, Rev. Sci. Instr. **21**, 643 (1950).

Invited Paper

F11. Energy Levels of Some Light Nuclei. R. G. HERB, *University of Wisconsin.* (30 min.)

WEDNESDAY AFTERNOON AT 2:00

Physics Building, Room 200

(C. C. LAURITSEN presiding)

Invited Papers

G1. Problems in the Understanding of the Semiconducting Properties of Germanium. W. H. BRATTAIN, *Bell Telephone Laboratories.* (30 min.)

G2. The Properties of $p-n$ Junctions in Germanium. G. L. PEARSON, *Bell Telephone Laboratories.* (30 min.)

G3. Physics Research in Europe. GORDON F. HULL, JR., *Office of Naval Research and Dartmouth College.* (30 min.)

THURSDAY MORNING AT 9:00

Physics Building, Room 200

(J. E. HENDERSON presiding)

Contributed Papers

H1. Meson Mass Ratio and Energetics of Meson Decay.* WALLACE BIRNBAUM, FRANCES M. SMITH, AND WALTER H. BARKAS, *University of California, Berkeley.*—The π/μ-meson mass ratio is being determined with new geometry, using similar range *vs* momentum relations as were employed in the measurement of the π-meson to proton mass ratio.[1] The π- and μ-mesons from the target were selected magnetically to enter the emulsion with approximately equal velocities. Two distinct range distributions corresponding to two distinct masses were found. The dispersion observed is in agreement with range straggling theory. Present statistics give the value for the π/μ-mass ratio as 1.317 ± 0.004. The absolute momentum, p_0, of the μ's from decay of π's stopping in the emulsion is also determined by comparison with μ's from the target which have momenta within a few percent of p_0. For this purpose, the absolute value of the magnetic field intensity of the 184-inch cyclotron has been mapped (using a nuclear flux meter) over the orbit of the mesons. Preliminary results give a value of 29.86 ± 0.06 Mev/C. From the above two basic results, and setting the mass of the "neutrino" involved in the $\pi-\mu$-decay equal to zero, we obtain: $\pi-\mu$-mass difference $=66.46\pm0.16M_0$, π-mass $=276.1\pm2.3M_0$, μ-mass $=209.6\pm2.4M_0$, as absolute values with no reference to the proton mass. The μ kinetic energy associated with $p_0=4.085\pm0.044$ Mev.

* This work was performed under the auspices of the AEC.
[1] Barkas, Smith, and Gardner, Phys. Rev. **82**, 102 (1951).

H2. Čerenkov Radiation from Protons and the Measurement of Proton Velocity and Kinetic Energy.* R. L. MATHER, *University of California, Berkeley.*—High velocity protons ($\beta=0.68$) from the electrically deflected external beam of the 184-inch cyclotron were sent through materials of high index of refraction, and light was detected photographically with the intensity and angular distribution characteristic of Čerenkov radiation as predicted by Frank and Tamm. By removing the effects of chromatic dispersion with a suitable prism, the angular intensity distribution was reduced to a bell-shaped distribution about the predicted angle with a standard deviation of around fourteen minutes of arc. The possibility that the angular distribution of Čerenkov radiation could be used as an absolute measure of the velocity of the proton, and hence its energy, has been exploited; and a device has been developed for this measurement. The resolution of the instrument is ±3.5 Mev, and the various effects which lower the resolution seem well understood. A nonconservative estimate of the accuracy with which the mean energy of the 340-Mev proton beam has been measured is ±0.8 Mev.

* This work was performed under the auspices of the AEC.

H3. An Analysis of the Self-Energy Problem for the Free Resting Electron. F. A. KAEMPFFER AND P. N. DAYKIN, *University of British Columbia.*—The self-energy of the free resting electron is calculated without the restriction that the radiation field of the electron be a purely retarded field. Both the one-electron theory and the hole theory of the positron are treated. It is shown that in the one-electron theory the normally quadratically divergent transverse part of the self-energy vanishes if the radiation field is assumed to be one-half retarded plus one-half advanced field, the remaining coulomb part of the self-energy being only linearly divergent. A similar theorem does not hold for the hole theory. A particular type of radiation field discussed by Stueckelberg leads to a vanishing self-energy in the one-electron theory. However, this does not solve the self-energy problem, as in this case radiation corrections for scattering will vanish as well.

H4. On the Feasibility of an Experiment to Observe the Exchange Effect in Positron-electron Scattering. J. R. H. DEMPSTER, *University of British Columbia.*—An estimate is made of the feasibility of a positron-electron scattering experiment to observe the exchange effect described by Bhabha on the basis of the hole theory of positrons. Such an experiment would be of particular interest, since it would afford a direct confirmation of the hole theory. The necessary calculations were carried out by Feynman's methods, with results in agreement (up to a factor 2) with those given by Bhabha. The results indicate that a successful experiment should be possible with careful technique. Suggestions are made regarding the best type of measurement at various energies.

H5. Nonlinear Meson Theories of Nuclear Forces. L. I. SCHIFF, *Stanford University.*—In earlier reports,[1] a qualitative account was given of nuclear saturation and the independent-nucleon model in terms of a nonlinear meson theory of nuclear forces. The nonlinearity was previously introduced into the free meson field, and was equivalent to a point contact repulsion between mesons. In place of this, the nonlinearity can be introduced into the coupling between mesons and nucleons, and then is equivalent to a suppression of meson emission and absorption by nucleons when mesons are already present. The latter formulation is in some respects simpler, since the source-free meson theory can be quantized in the usual way. Also, the classical field equation is readily solved outside the source region. Qualitatively, the two formulations are similar and lead to analogous predictions concerning physical phenomena. A quantitative comparison will be presented.

[1] L. I. Schiff, Phys. Rev. **80**, 137 (1950); Bull. Am. Phys. Soc. **26**, No. 3, 48 (1951), abstract WA5.

H6. Effect of Nuclear Symmetry on Dipole Transitions in Light Nuclei. L. E. H. TRAINOR, *University of Minnesota.*—The effect of nuclear symmetry on dipole transitions in light nuclei has been investigated using the independent particle model and Wigner's theory of the symmetric hamiltonian. On this model symmetry selection rules operate in addition to the usual selection rules to reduce the amount of nuclear dipole radiation. A detailed study has been made of the He^4 nucleus. The lowest excited state $^1P_1$ (completely symmetric) has zero-transition dipole moment to the ground $^1S_0$ state on this model, and the strong 21.6-Mev dipole transition observed[1,2] when protons are captured by tritium is due to the higher (symmetric on only three particles) $^1P_1$ level. Thus, the theory predicts an excited bound state of the He^4 nucleus. To explain the angular distribution of the gamma-rays, spin-orbit and tensory forces were introduced. Limitations of the model used, and extension of the symmetry selection rule to more general assumptions will be discussed.

[1] Argo, Gittings, Hemmendinger, Jarvis, and Taschek, Phys. Rev. **78**, 691 (1950).
[2] Jarvis, Hemmendinger, Argo, and Taschek, Phys. Rev. **79**, 929 (1950).

H7. Absorption of Extensive Showers by Water.* PAUL H. BARRETT,† *University of California, Berkeley.*—Decoherence curves were measured on the surface and under various depths (up to 10 m) of water at Lake Sabrina, California (2765 m elevation). Coincidence circuits were arranged to detect the presence of multiple cores in extensive showers. Results indicate that if multiple cores exist, they must have a lateral separation of less than 50 cm. Evidence is obtained that shows the photon distribution near the core to be more sharply peaked than the electron distribution. A theoretical calculation which assumes identical electron and photon distribution functions predicts the decoherence curves underwater to be obtained by a scale change from the decoherence curve with no absorber. The results of this calculation do not agree with experiment. The density and number spectra of extensive showers are calculated for this elevation.

* Assisted by the joint program of the ONR and AEC.
† AEC Predoctoral Fellow.

H8. Further Cloud Chamber Observation of *V*-Particles.* W. B. FRETTER, *University of California, Berkeley.*—Observation of *V*-particles has continued in a cloud chamber containing lead plates but without a magnetic field.[1] The total number observed to date is 36 uncharged and 8 charged particles. One of the uncharged particles disintegrates into a proton and a meson, the particles being identified only roughly by range, scattering, and ionization. Assuming a two-particle decay, some information can be obtained by considering the angular distribution of the product particles. It is not yet clear whether all events can be attributed to the decay of a particle slightly heavier than a proton, or whether another lighter *V*-particle may be involved. In some cases the presence of a third decay particle may be necessary, since the plane of the product particle does not line up with the original event. One picture shows evidence that one of the decay products of the charged *V*-particle is a neutron.

* Assisted by the joint program of the ONR and AEC.
[1] W. B. Fretter, Bull. Am. Phys. Soc. **26**, No. 1, 7 (1951).

H9. On the Mass of Neutral *V*-Particles.* R. B. LEIGHTON, A. J. SERIFF, AND C. D. ANDERSON, *California Institute of Technology.*—Measurements of the magnetic curvature and specific ionization of the two charged particles which result from the decay of neutral *V*-particles have shown that, at least in some cases, the masses of the particles differ markedly from one another, and seem to be approximately equal, respectively, to those of a proton and a meson. So far, in these cases, the particle of greater mass has carried a positive charge and the meson a negative charge, although mesons of positive charge have been observed where the mass of the second charged particle could not be estimated. On the assumption that the decay products are a proton and pi-meson, and that no neutral particles are produced, the above measurements lead to mass values which range from 2220 to 2265 electron masses for the *V*-particle, corresponding to a disintegration energy of 50 to 70 Mev. Other types of data, however, some of which have been previously reported,[1] indicate that the decay scheme is not necessarily that assumed above, so that (1) neutral *V*-particles may not have a single mass or (2) neutral particles may be present among the decay products. In the latter event, the mass value of the neutral *V*-particle calculated as above corresponds to a lower limit.

* Assisted by the joint program of the ONR and AEC.
[1] Seriff, Leighton, Hsiao, Gowan, and Anderson, Phys. Rev. **78**, 290 (1950). Armenteros, Barker, Butler, Cachon, and Chapman, Nature **167**, 501 (1951).

H10. The Directional Asymmetry of the Ratio of Positive to Negative Cosmic-Ray Mesons.* ROBERT V. PYLE, *University of California, Berkeley.*—The positive to negative ratio of cosmic-ray mesons in the 1-Bev to 2-Bev energy range is being measured as a function of zenith angle. At this latitude (Berkeley, 38°N) there should be no appreciable asymmetry due to the action of the earth's magnetic field on the primary radiation; all asymmetries are produced within the atmosphere. Separation of charge is effected in passage through 24 inches of iron magnetized to 18,800 gauss. The arrangement of the Geiger counters which detect the mesons is such that the scattering correction is negligible. Preliminary results indicate the positive to negative ratio is about 1.55 at 60° West zenith angle, 1.24 in the vertical direction, and 0.95 at 60°E. No variation with zenith angle is observed in the north-south plane. The results will be compared with theoretical predictions.

* Assisted by the joint program of the ONR and AEC.

H11. An Incomplete Cosmological Model.* GUY C. OMER, JR., *The University of Chicago.*—Astronomers are seriously questioning the previous estimations of extragalactic distances. Many difficult astronomical problems are involved which have not been solved. Since the scale of distances within the universe is open to so much suspicion, the problem of constructing cosmological models upon necessarily incomplete data is considered. The time-scale and the red-shift appear to demand a M_1 monotonically expanding model with a positive cosmological constant. The red-shift relation may impose an upper limit upon the inhomogeneity of the model. However, the curvature of space and the average density of matter appear at present to be indeterminant.

* This work was partially supported by the ONR.

H12. Conservation Laws in Feynman's Modified Electrodynamics. P. N. DAYKIN, *University of British Columbia.*—In Feynman's treatment of the electron self-energy problem, the divergence is eliminated by introducing a convergence factor into the integral over the virtual photon momentum space. Feynman[1] has remarked that his choice of convergence factor is inconsistent with the conservation of energy for the radiation field of an atom. This problem is examined in a more general way. The modification of the maxwell equations effected by the convergence factor is deduced. The equations satisfied by the modified field belong to the generalized electrodynamics described by Podolsky.[2] The modified energy-momentum tensor consistent with this electrodynamics is shown to satisfy the conservation law for the field with source.

[1] R. P. Feynman, Phys. Rev. **76**, 778 (1949).
[2] B. Podolsky, Phys. Rev. **62**, 68 (1942).

H13. Two Unstable *V* Mesons Observed in a Cloud Chamber at Sea Level.* EDWARD J. ALTHAUS,† *Washington University.*—In the course of observations[1] on μ-meson capture in Pb and C with a cloud chamber triggered by neutron-coincidences and without a magnetic field, two events out of 1215 pictures were observed that had characteristics similar to those of the *V* mesons first found by Rochester and Butler and subsequently by C. D. Anderson and others.[2] One of the events has been identified as a V_0, namely, one in which a fork occurs in the gas, apparently as the result of decay of a neutral particle of short life. Both legs are above minimum in ionization, and there is a star in a Pb plate which could be the origin of the neutral particle. The other appears to be a $V_\pm$ or a recoil-less deflection of a minimum density track in the gas, which has been interpreted as the decay of a charged particle heavier than a π-meson into a neutral and a charged particle. The particle subsequently passed through the Pb plate and stopped in a carbon plate. Other interpretations will be discussed.

* Supported by the ONR and AEC.
† Now at the University of Southern California.
[1] E. J. Althaus, Phys. Rev. **81**, 647A (1951).
[2] G. D. Rochester and C. C. Butler, Nature **160**, 855 (1947). Seriff, Leighton, Hsaio, Cowan, and Anderson, Phys. Rev. **78**, 290 (1950). V. D. Hopper and S. Biswas, Phys. Rev. **80**, 1099 (1950).

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Green, David and J. Reginald Richardson—E4
Harrison, Melvin A. and Ronald Geballe—A1
Haslam, R. N. H., L. A. Smith, and J. G. V. Taylor—B2
Heckrotte, W. and L. Schecter—F7
Herb, R. G.—F11
Herman, L. and H. Leinbach—C7
Hess, F. G.—B8
Holmes, John R. and Lee W. Parker—C9
Horsley, R. J., H. E. Johns, and R. N. H. Haslam—B3
Horwood, J. L. and G. G. Eichholz—B5
Hubbard, Harmon W.—F2
Hull, Gordon F., Jr.—G3
Jacobsohn, B. A.—B1
Kaempffer, F. A. and P. N. Daykin—H3
Kane, W. R. and K. C. Clark—C2
Katz, L. and A. G. W. Cameron—E8
Leighton, R. B., A. J. Seriff, and C. D. Anderson—H9
Lewis, W. B.—B12
Li, C. W., Ward Whaling, W. A. Fowler, and C. C. Lauritsen —B11
Little, Edward M.—D1
Lundby, Arne and L. Marshall—B7
Mann, K. C. and G. H. Hanson—F1
Martin, A. B., R. D. Johnson, and W. V. Goeddel—A8
Mather, R. L.—H2
McGeer, P. L., G. B. Rathmann, A. J. Curtis, and C. P. Smyth—D6
Montalbetti, R. and L. Katz—E9
Moon, J. H. and A. L. Thompson—E10
Moore, Richard L.—D8
Mukherjee, N. R. and Oliver Row—D7
Omer, Guy C., Jr.—H11
Pearson, G. L.—G2
Platt, Virginia P. and Ronald Geballe—A2
Post, R. F.—B4
Potter, D. S., Gerald Garrison, Charles E. Miller, Wayne Sandstrom, and Jay Todd, Jr.—F9
Powell, Wilson M.—F4
Pyle, Robert V.—H10
Richardson, J. R.—E11
Rinehart, John S., William A. Allen, and W. C. White—D5
Rogers, F. T., Jr., and L. E. Schilberg—A6
Schiff, L. I.—H5
Schilberg, L. E. and F. T. Rogers, Jr.—A5
Schoof, W. W. and R. D. Hill—E6
Schrank, Glen E. and J. Reginald Richardson—E3
Seagrave, J. D.—B10
Shiren, N. S. and R. F. Post—B6
Smellie, D. W. and H. E. Petch—E1
Trainor, L. E. H.—H6
Warburton, F. W.—D2
Weissler, G. L. and Po Lee—C8
White, W. C., John S. Rinehart, and William A. Allen—D4
Wilcox, Howard A.—D9
Williams, John H.—D11
Wilson, William S.—C11